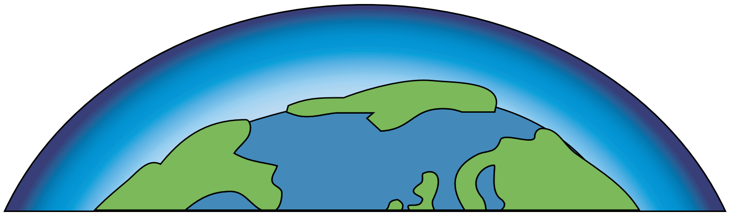


Lesson 6: Stratospheric Ozone and Ultraviolet Light

Students explore how the creation and destruction of ozone protects us from ultraviolet radiation (UV). Students kinesthetically model the depletion of ozone caused by chlorofluorocarbon (CFC) molecules.

Main Concept: The creation and destruction of ozone in the stratosphere protects life on Earth from harmful ultraviolet radiation.

Scientific Question: How does ozone protect life on Earth from ultraviolet radiation?

Objectives	Standards
• Students will explain and diagram how ozone is created and destroyed in the stratosphere due to ultraviolet radiation energy from the Sun. • Students will explain the consequences of overexposure to ultraviolet radiation. • Students will explain how certain substances interfere in the ozone creation/destruction process therefore allowing more ultraviolet radiation to strike Earth's surface.	**Addresses:** NSES: B 5-8 3.6 NSES: B 5-8 1.1 NSES: F 5-8 1.7 NSES: A 5-8 #1 2061: 6E 6-8 #5

Assessment	Abstract of Lesson
Responses to Astro Journal questions and poster of how ozone is created and destroyed.	Students use ultraviolet beads to "discover" ultraviolet radiation, and discuss the effects of ultraviolet radiation on humans. Students model and create a poster of how ozone is created and destroyed and how this process helps to protect us from ultraviolet radiation. Students read about the ozone layer and model the depletion of ozone due to CFC molecules.

Prerequisite Concepts	Major Concepts
• Humans need oxygen, carbon dioxide, nitrogen, ozone, and water vapor in certain quantities. (Atmosphere Lesson 1) • Properties of a gas describe unique characteristics of a gas. (Atmosphere Lesson 1) • A chemical change or reaction occurs when molecules change or transform by combining with other substances, interchanging atoms with another molecule, or by breaking down into separate atoms. (Atmosphere Lesson 4) • Oxygen is a highly reactive element that rapidly combines with other atoms and molecules. (Atmosphere Lesson 5)	• Ultraviolet radiation is invisible light that comes from the Sun. Ultraviolet radiation harms animals and some plants by causing sunburn, and large exposure can cause skin cancer. • When ultraviolet radiation strikes molecules of oxygen gas (O_2), it splits the molecule into two single oxygen atoms, which can then combine with an oxygen gas molecule (O_2) to form a molecule of ozone (O_3). When an ozone molecule (O_3) absorbs ultraviolet radiation, it splits into an oxygen gas molecule (O_2) and a free oxygen atom, which may join up with an oxygen molecule to make another ozone molecule, or it may steal an oxygen atom from an ozone molecule to make two ordinary oxygen molecules. • The absorbing of ultraviolet radiation by oxygen gas and ozone molecules prevents much of the ultraviolet radiation from reaching the Earth and harming animals and some plants.

Suggested Timeline (45-minute periods):
Day 1: Engage Section
Day 2: Explore Section
Day 3: Explain
Day 4: Extend and Evaluate Sections

Materials and Equipment:
- Gas Reference Chart
- Chemical Diagram Sheet
- A class set of Astro Journal Lesson 6
- A class set of Ozone Reading
- Name tags
- Poster paper
- Flashlight

Sun Bead Activity (each student will need the following):
- 4 ultraviolet (UV) beads
- 2 pipe cleaners

Note to Teacher: UV beads can be found at most science educational supply stores such as:
Educational Innovations http://www.teachersource.com or
Sundance Solar http://store.sundancesolar.com

Optional UV Investigation (Materials will vary with each student's investigation, but some of the materials they may need are as follows.)
- Additional UV beads
- Sunscreens of different levels of protection
- Sunglasses with and without UV protection

Ozone Research
- Computers with Internet connection and Web browsers
- Library

Preparation:
- Gather materials.
- Duplicate Astro Journal, Gas Reference Chart, and Ozone Reading.
- Prepare chart paper with the major concept of the lesson to post at the end of the lesson.

Differentiation:

Accommodations
For students who may have special needs:
- Have them work with a partner on the Astro Journal writing or report orally to the teacher.
- Have them work with a partner on the research and reading sections.

Advanced Extensions
For students who have mastered this concept:
- Research and report on the electromagnetic spectrum. What other forms of radiation are there? What is the difference between radiation that we can see and radiation we cannot see? Are there other forms of radiation that are harmful to humans?

Engage **(approximately 45 minutes** not including the Optional UV Investigation**)**

1. **Review unique properties of gases (Atmosphere Lesson 2) and of carbon dioxide, water vapor (Atmosphere Lesson 3), and oxygen (Atmosphere Lesson 5).**
   - Question: So far, what gases have we learned about in our atmosphere and what unique properties make them important to human life?
   - *Answer: We've learned that water vapor and carbon dioxide absorb heat and reradiate it back to Earth, which plays a role in determining the surface temperature of our planet. We've learned that oxygen is very reactive, and releases heat when it reacts, sometimes resulting in fire. We also learned that oxygen helps us to get energy from sugars.*

2. **Draw on student's prior knowledge of the dangers of ultraviolet radiation.**
   - Question: We know that the Sun is important to our survival, but how can the Sun also be harmful to us?
   - *Answers may include: We can get a sunburn or skin cancer from the Sun.*

   - Question: What kinds of things do we do to protect ourselves from the Sun?
   - *Answers may include: We put on sunscreen, cover our skin with clothes, wear a hat, sit in the shade, or wear special sunglasses.*

3. **Bridge to this lesson and introduce the purpose.**
   - Say: Today we're going to learn about how the Sun can harm us and ozone's unique properties that help to protect us from the Sun.

   - Question: What do you already know about ozone either from previous experience or from the Atmosphere Training module?
   - *Answers may include: Ozone makes up a very small percentage of our atmosphere and is located in the stratosphere and troposphere. The effects of too little ozone on life were that some plants and animals died.*

4. **Guide students in the Sun Bead Activity.**

   Note to Teacher: make sure your classroom curtains are closed so that sunlight is not allowed into the classroom for this activity.

   - Question: How are the lights in this classroom different from sunlight?
   - *Answer: (Accept all reasonable answers.) Answers may include: The classroom lights are man-made, and the sunlight is natural. Sunlight is brighter.*

   - Give students four ultraviolet beads each and two pipe cleaners each.

   - Tell students that they are going to do an experiment to see another important difference between sunlight and man-made lights. Have them put two of their beads on one pipe cleaner and two on the other pipe cleaner. Twist the ends of each pipe cleaner together to form a ring or bracelet, so that the beads don't fall off and get lost.

- Tell students that they will be exposing two of their beads to the classroom lights and two of their beads to the sunlight. Have them predict in their Astro Journals what will happen to the two sets of beads and why.

- Have students take two of their beads outside and observe what occurs. The beads will change from white or silver to a deep color.

- Have students record their observations in their Astro Journals.

- Question: What happened to the beads that were exposed to sunlight?
- *Answer: They changed colors.*

- Question: What happened to the beads that were left inside?
- *Answer: They stayed the same.*

- Question: What does this tell you about the difference between sunlight and man-made lights?
- *Answer: Sunlight puts out something that man-made lights do not.*

- Say: Sunlight puts out light that we can see, but it also puts out light that we cannot see with our eyes. One of the kinds of light that the Sun puts out is ultraviolet radiation. Sometimes ultraviolet radiation is called UV.

- Question: Where have you heard about or seen UV before?
- *Answers may include: Sunglasses or sunscreen have UV protection.*

- Question: Why do we worry about UV protection? What does ultraviolet light do to us?
- *Answer: Too much ultraviolet light burns our skin and can cause skin cancers.*

Note to Teacher: Here is a more detailed explanation of how UV harms life that may be useful to students who are familiar with DNA and cell structures. DNA absorbs UV-B light and the absorbed energy can break bonds in the DNA. Proteins present in the cells nucleus repair most of the breakages, but unrepaired genetic damage of the DNA can lead to skin cancers. If you or your students are interested in further researching Ultraviolet radiation and the electromagnetic spectrum, here are a few places to get started:

- Ultraviolet Radiation: How it Affects Life on Earth: Earth Observatory Web site: http://eob.gsfc.nasa.gov/Library/UVB/uvb_radiation3.html

- UV radiation exposure, ozone creation and depletion: Visible Earth Web site: http://visibleearth.nasa.gov/Atmosphere/Radiation_Budget/Ultraviolet_Radiation.html

- Understanding Solar Spectra - Fun with Spectra on SERTS (Solar Extreme-ultraviolet Rocket Telescope) http://orpheus.nascom.nasa.gov/serts/

- Electromagnetic spectrum: Imagine the Universe Web site: http://imagine.gsfc.nasa.gov/docs/science/know_l2/emspectrum.html

- Citizen Explorer Satellite: http://citizen-explorer.colorado.edu

5. **(Optional) You may want to engage students in a UV Investigation using UV beads. For example, students could test the UV protection of different sunscreens to see how well they work with the beads.**
    - Have students come up with the question they'd like to explore using the UV beads and provide a hypothesis of what they think will happen.
    - Have them design and carry out the experiment. Make sure they collect observational data during their experiment, record their results, and draw conclusions.
    - Guidelines for this activity are provided in the Astro Journal.

6. **Introduce the Scientific Question and focus on how ozone provides protection from ultraviolet radiation.**
    - Question: Thinking back to when we modeled ozone gas, what is ozone made of?
    - *Answer: Ozone is made of three oxygen atoms.*
    - Question: How does this compare to oxygen gas molecules?
    - *Answer: Oxygen gas is composed of two oxygen atoms.*
    - Have students look at the Gas Reference Chart.
        - Question: When you look at the amounts of oxygen and ozone in the atmosphere, how do they compare?
        - *Answer: There is significantly more oxygen than ozone.*
        - Question: What does this tell you about ozone?
        - *Answer: (Allow students to discuss their ideas about this.)*
    - Say: In the next activity, we'll look at how ozone is produced, why there is so little of it, and how ozone is important to human survival.
    - The Scientific Question we will explore is:
        - How does ozone protect life on Earth from ultraviolet radiation?
    - Have students record their predictions to the Scientific Question in their Astro Journals.

Explore (approximately 45 minutes)

1. **Lead students in the Physically Modeling Ozone Activity.**
    - Say: Ozone is made of three atoms of oxygen. It is made when a strong energy source such as lightning passes through oxygen molecules, O_2.
    - Have students physically form oxygen gas molecules, as they did in the Extend Day 2 Section of Atmosphere Lesson 2. Modeling oxygen gas requires two students who hold both hands out to "bond" with each other. (Each student represents one oxygen atom.)
    - Point out the stratosphere on the layers of the atmosphere in the Gas Reference Chart.
    - Say: In the stratosphere, ultraviolet radiation from the sun forms ozone. As the radiation hits an oxygen molecule, it splits it into two oxygen atoms and energizes the two oxygen atoms that made up that molecule.

- Have one pair of students split apart and act energized.

- Say: These energized atoms move around quickly until they run into regular oxygen molecules. This is how ozone in the stratosphere is made.

- Have the energized oxygen atoms attach themselves to a pair of students who form an oxygen gas molecule. The energized oxygen atoms should place one hand on the shoulder of one of the students in the oxygen gas molecule to demonstrate the bonding.

- Question: Does this molecule seem strong and stable?
- *Answer: No. The third oxygen atom is not strongly attached to the molecule.*

- Say: When more radiation strikes the ozone molecule, the loosely-attached oxygen atom breaks off to either form a new ozone molecule with a regular oxygen gas molecule (O_2) or to form a regular oxygen gas molecule (O_2) with another free oxygen atom.

- Have two groups of students modeling an ozone molecule (O_3) breakup the ozone molecules and form an oxygen gas molecule.

- Say: The ultraviolet radiation is absorbed both when ozone is created and destroyed. If ultraviolet radiation encounters oxygen or ozone, it will not reach Earth's surface.

- Have student oxygen molecules start to move around the room. Use a flashlight to model ultraviolet radiation. When the light hits an oxygen molecule, students should respond accordingly. When the light hits an ozone molecule, it should split apart. Help students to respond properly as they break their molecules apart and reform them.

- Say: Ozone is constantly being created and destroyed as ultraviolet radiation hits the stratosphere. When the radiation does not encounter oxygen or ozone, it is able to reach Earth's surface where it can be harmful to life. This process of creating and destroying ozone is balanced. While ozone is being destroyed, an equal amount is being created. Think of this like a leaky bucket. As long as water is poured into the bucket at the same rate that the water is leaking out, the amount of water in the bucket will stay the same. So too will the amount of ozone stay the same as long as the rate at which it is created stays the same as the rate at which it is destroyed.

  Note to Teacher: Very little UV-B (the type of UV that causes cancer) is absorbed by O_2, but O_3 absorbs UV-B very well. This is why we need both O_2 and O_3.

- Have students create a poster with captions that shows how ozone is created and destroyed by ultraviolet radiation.

- Have students compare and contrast their predictions about ozone with the facts in their Astro Journals.

Explain (approximately 45 minutes)

1. **Have students share their posters and discuss how ozone is created and destroyed by ultraviolet radiation.**

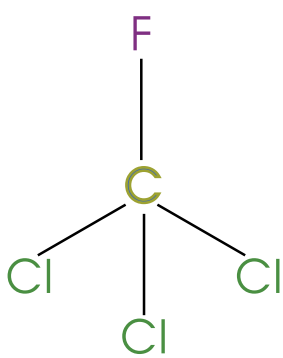
2. **To gain further understanding of ozone, have students read the Ozone Reading and answer the reading questions in their Astro Journals.**

3. **Discuss the Ozone Reading.**
   - Question: How can humans harm ozone?
   - *Answer: Human activities can create chlorofluorocarbons (CFCs), which destroy ozone.*

   - Question: How is ozone both helpful and harmful to human survival?
   - *Answer: Ozone harms life if it comes in contact with it on Earth's surface, because it is highly reactive. Ozone protects us, when it is high up in the stratosphere and absorbs ultraviolet radiation, which can cause skin cancer.*

Extend/Apply (approximately 25 minutes)

1. **Guide students in the Ozone Depletion Activity.**
   - Guide students to model a chlorofluorocarbon (CFC) molecule, 3-5 free oxygen atoms and 3-5 ozone molecules. You may want to have students wear name tags or labels of the atoms they will represent.



Chlorofluorocarbon (CFC)

   - Modeling a CFC requires two students to represent a single carbon atom who stand back to back and each hold out two hands to "bond" with four students. Three of these students represent chlorine atoms by holding out one arm to bond with the carbon, and hold the other arm at their side. A fourth student represents a fluorine atom by holding out one arm to bond with the carbon holding the other arm at their side. (A CFC molecule will require 6 students.)

- Modeling ozone requires two students who hold both hands out to "bond" with each other and a third student who places a hand on the shoulder of one of the other students. (Each student represents one oxygen atom. Each ozone molecule will require 3 students. To form 3-5 ozone molecules, 9-15 students will be required.)

- Modeling a free oxygen atom requires a single student who holds both hands out ready to bond.

• Place molecules and atoms.
  - Have the ozone molecules spread out in a line. Place a free oxygen atom close to each ozone molecule. It will be important to keep free oxygen atoms away from other free oxygen atoms and from ozones, since there would be a tendency to react. (You may want to discuss with students how the free oxygen atoms might have formed by an oxygen gas molecule or ozone molecule that absorbed radiation.)

  - Tell students that a CFC has been released from a factory and that it's pretty stable, so it doesn't break up or react while in the troposphere. In fact, the ozone is protecting the CFC from ultraviolet radiation, which would otherwise break it up. (Have the 6 students modeling the CFC, move toward the line of ozone molecules.)

  - Tell students that now the CFC has made its way up to the stratosphere where its no longer shielded from ultraviolet radiation. When hit with ultraviolet radiation, CFCs are energized and release their chlorine atoms. (Shine a flashlight on the CFC molecule. Have them act energized and release one of the chlorine atoms.)

• Model the reaction.
  - Have the released chlorine react with an ozone molecule, by taking the oxygen loosely bonded to form chlorine monoxide (ClO) and a regular oxygen gas molecule (O_2).

  - Tell students that if a chlorine atom only destroyed one ozone molecule, it wouldn't be a problem, but there is more to the story.

  - Have the chlorine monoxide (ClO) encounter a free oxygen atom. The free oxygen atom will steal the oxygen atom from ClO to form oxygen gas (O_2) (which is more stable) and release the chlorine atom.
    • Question: What is this chlorine atom going to do now?
    • *Answer: It will react with another ozone molecule. (Have students model this reaction with the next ozone molecule, again forming ClO and O_2.)*

    • Question: Now what will happen when chlorine monoxide encounters the free oxygen atom?
    • *Answer: The free oxygen atom will steal the oxygen atom from the chlorine monoxide to form oxygen gas and a free chlorine atom. (Have students model this reaction. Then have them continue to model the next reaction between the chlorine and the next ozone and so forth until the chlorine makes it to the end of the line.*

• Discuss the results and conclusions.
  - Question: Do we now have more oxygen or more ozone?
  - *Answer: We have more oxygen.*

  - Question: So is the creation of ozone balanced with the destruction?
  - *Answer: No. More ozone is being destroyed than created.*

  - Question: How many chlorine atoms did it take to destroy all of our ozone molecules?
  - *Answer: It only took one.*

- Question: So what would happen if our CFC released all of its chlorine atoms?
- *Answer: Ozone would be destroyed more quickly. (You may want to have students model this by repeating the above activity only have the CFC release all chlorine atoms, instead of just one. When modeling this a second time, you may also want to shine your flashlight on the oxygen gas molecules to form ozone, to show that ozone is being created, but not as quickly, as it is being destroyed.)*

- Question: In the process of destroying ozone, was any matter destroyed? Explain.
- *Answer: No. The atoms still exist, but they formed new molecules.*

- Question: Can ozone be created again?
- *Answer: Yes, ozone can be created again, but it cannot be created as quickly as it is being destroyed.*

- Question: So if we use the idea of the ozone layer being like a leaky bucket, what happens to the bucket?
- *Answer: Since more water (or ozone) is leaking out than is being poured into the bucket, then the level of water in the bucket doesn't stay the same, it gets lower.*

- Question: If there is less ozone, then what is happening to life on Earth?
- *Answer: Ultraviolet radiation is getting through to the Earth's surface and harming animals and some plants.*

- Question: What would happen if more CFC molecules made it to the ozone layer?
- *Answer: More ozone would be depleted and more radiation would get through.*

Evaluate (approximately 20 minutes)

1. Have students complete their write-ups in their Astro Journals.

2. Discuss students' responses in their Astro Journals to ensure that they have mastered the major concepts.

- Question: What is ultraviolet radiation and how does it affect human life?
- *Answer: Ultraviolet radiation is light that comes from the Sun but is not visible to our eyes. It causes our skin to burn and a lot of exposure can cause skin cancers.*

- Question: How does ozone protect us from ultraviolet radiation?
- *Answer: When ultraviolet radiation strikes molecules of oxygen gas (O_2), it splits the molecule into two single oxygen atoms, which can then combine with an oxygen gas molecule (O_2) to form a molecule of ozone (O_3). When an ozone molecule (O_3) absorbs ultraviolet radiation, it splits into an oxygen gas molecule (O_2) and a free oxygen atom, which may join up with an oxygen molecule to make another ozone molecule, or it may steal an oxygen atom from an ozone molecule to make two ordinary oxygen molecules. The absorbing of ultraviolet radiation by oxygen gas and ozone molecules prevents much of the ultraviolet radiation from reaching the Earth and harming animals and some plants.*

- Question: What causes ozone depletion?
- *Answer: Chlorofluorocarbons (or CFCs) react with ozone molecules, so that much more ozone is destroyed than normal. This disrupts the balance so less ozone is available to absorb harmful radiation.*

- Question: What is the difference between ozone destruction and ozone depletion?
- *Answer: Ultraviolet radiation causes ozone destruction when it hits ozone molecules and breaks them apart to form oxygen gas molecules or new ozone molecules. Ozone depletion is caused by chlorofluorocarbons, which react with ozone so that less ozone is available to absorb UV radiation.*

3. Collect students' Astro Journals and evaluate them to ensure that they have each mastered the major concepts:

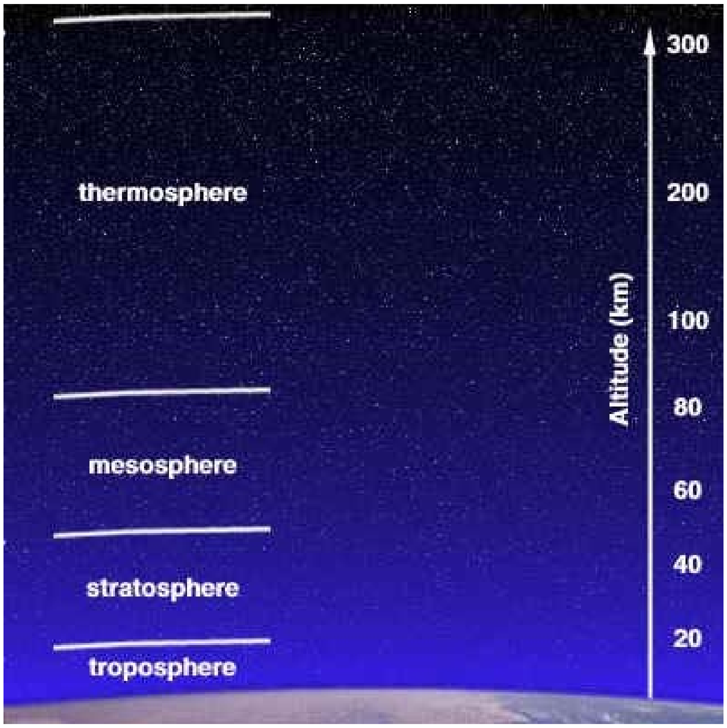
- The creation and destruction of ozone in the stratosphere protects life on Earth from harmful ultraviolet radiation.

4. Bridge to next lesson.

- Today we learned about how ozone protects us from ultraviolet radiation. In this lesson and the last lesson, we've been talking about molecules made of oxygen that are important because oxygen is highly reactive. In the next lesson, we'll look at how gases that do not tend to react can also be important to life.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

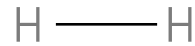
Gas Reference Chart



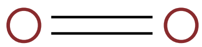
Gases	Location in the atmosphere	Amount in the Earth's atmosphere
Carbon dioxide (CO_2)	troposphere	0.035%
Water vapor (H_2O)	troposphere	1 to 4%
Oxygen (O_2)	troposphere	21%
Ozone (O_3)	stratosphere	300 Dobson Units
Nitrogen (N_2)	troposphere	78%
Methane (CH_4)	troposphere	0.0002%
Argon (Ar)	troposphere	0.9%
Neon (Ne)	troposphere	0.002%
Helium (He)	troposphere	0.0005%
Krypton (Kr)	troposphere	0.0001%
Hydrogen (H_2)	troposphere	0.00005%

Chemical Diagrams Sheet

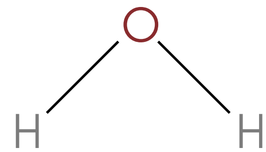
Carbon Dioxide (CO_2)



Hydrogen Gas (H_2)

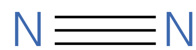


Oxygen Gas (O_2)

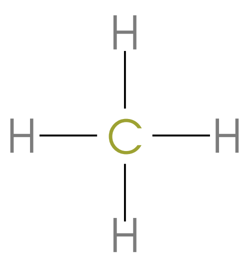


Water (H_2O)

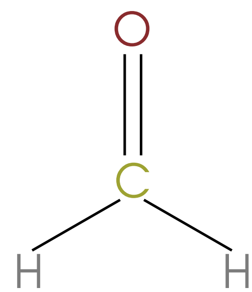
Ozone Gas (O_3)



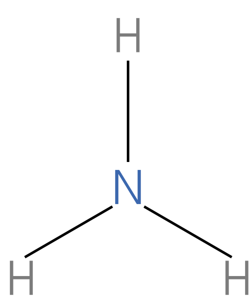
Nitrogen Gas (N_2)



Methane (CH_4)



Formaldehyde (CH_2O)



Ammonia (NH_3)

Astro Journal Atmosphere Lesson 6:
Ozone and Ultraviolet Light

Name:

Class/Period:

Date:

Predict how ozone protects Earth from harmful ultraviolet radiation.

Compare and contrast your prediction with what you have learned.

Sun Bead Activity

Predict what will happen to the beads exposed to the classroom light and to the beads exposed to the sunlight. Why do you think this?

Compare and contrast your prediction with what you have learned.

Astro Journal Atmosphere Lesson 6:
Ozone and Ultraviolet Light

Class/Period:

Name:

Date:

Optional Sun Bead Investigation

What scientific question can you explore using the Sun beads?

What experiment will you conduct with the Sun beads that will help to answer your scientific question? Describe the steps you will take and what materials you will need.

Materials:

Procedure:

What is your hypothesis of what the outcome will be? Why do you think that?

Record your data of your observations during your experiment.

What were the results of your experiment? How do your results compare to your prediction? What conclusions can you draw?

Astro Journal Atmosphere Lesson 6:
Ozone and Ultraviolet Light

Class/Period:

Name:

Date:

Ozone Reading

How can humans harm the ozone layer?

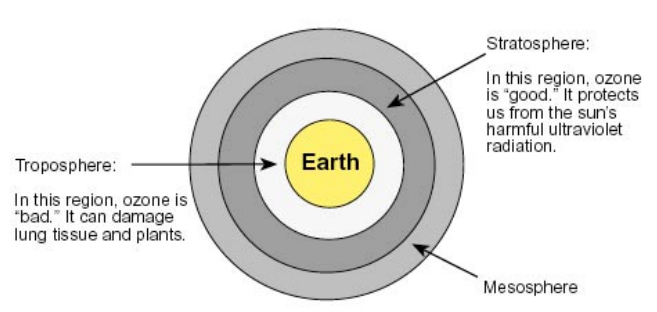
Explain how ozone can both harm and help human survival.

Ozone Depletion Activity

Draw and explain the process of ozone depletion.

What is the difference between ozone destruction and ozone depletion?

Ozone Reading

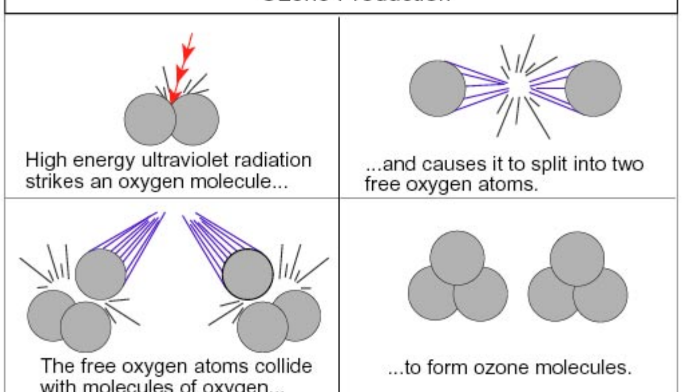


Ozone in Earth's Atmosphere

Ozone is a **molecule** made up of three atoms of **oxygen**. Most ozone is found in an area of Earth's **atmosphere** known as the **stratosphere**. Ozone is crucial for life on Earth. High in the atmosphere about 15 miles (24 km) up, ozone acts as a shield to protect Earth's surface from the sun's harmful **ultraviolet radiation**. Without this shield, we would be more vulnerable to skin cancer, cataracts, and impaired immune systems.

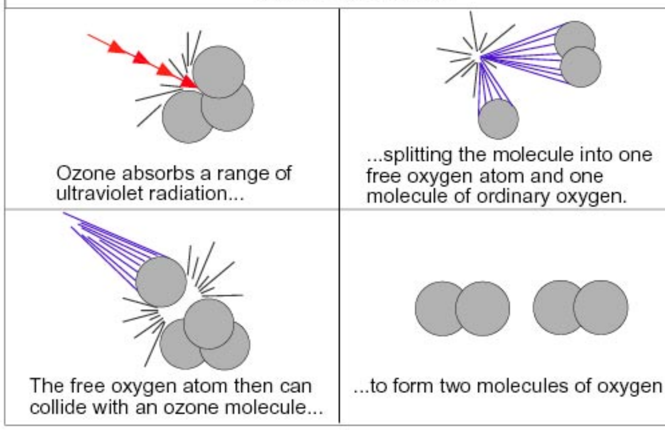
In the stratosphere, the air is bombarded with ultraviolet radiation from the sun. When those ultraviolet rays strike molecules of ordinary oxygen gas (O_2), they split the molecule into two single oxygen atoms. A freed oxygen atom then can bump into an oxygen molecule (O_2), and form a molecule of ozone (O_3).

Ozone Production



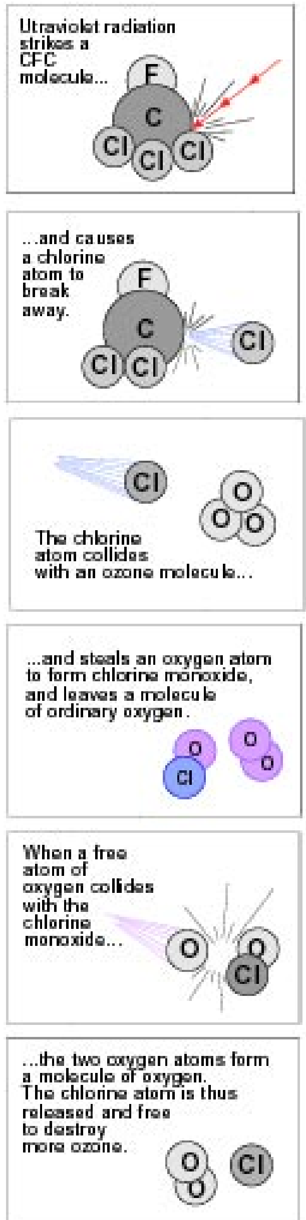
The characteristic of ozone that makes it so valuable to us--its ability to absorb ultraviolet rays--also causes its destruction. When an ozone molecule (O_3) absorbs ultraviolet radiation, it splits into an ordinary oxygen molecule (O_2) and a free oxygen atom (O). The free oxygen atom then may join up with an oxygen molecule to make another ozone molecule, or it may steal an oxygen atom from an ozone molecule to make two ordinary oxygen molecules.

Ozone Destruction



Over the Earth's lifetime, natural processes have kept the balance of ozone in the stratosphere. A simple way to understand the ozone balance is to think of a leaky bucket. As long as water is poured into the bucket at the same rate that water is leaking out, the amount of water in the bucket will remain the same. So, as long as ozone is being created at the same rate that it is being destroyed, the total amount of ozone will remain the same.

Scientists have found evidence that human activities are disrupting the ozone balance. Human production of chemicals such as **chlorofluorocarbons** (CFCs) has added another force that destroys ozone. CFCs are molecules made up of chlorine, fluorine and carbon atoms bound together. One of the few things that can break up CFC molecules is ultraviolet radiation. In the lower atmosphere, however, CFCs are protected from ultraviolet radiation by the ozone layer. CFC molecules are able to migrate intact up into the stratosphere.



Once in the stratosphere the CFC molecules are no longer shielded from ultraviolet radiation by the ozone layer. Bombarded by the sun's ultraviolet energy, CFC molecules break up and release their chlorine atoms. The free chlorine atoms then can react with ozone molecules, taking one oxygen atom to form chlorine monoxide and leaving an ordinary oxygen molecule.

If each chlorine atom released from a CFC molecule destroyed only one ozone molecule, CFCs probably would pose very little threat to the ozone layer. However, when a chlorine monoxide molecule encounters a free atom of oxygen, the oxygen atom breaks up the chlorine monoxide, stealing the oxygen atom and releasing the chlorine atom back into the stratosphere to destroy more ozone. This reaction happens over and over again, allowing a single atom of chlorine to destroy many molecules of ozone. If humans stop putting CFCs into the stratosphere, the ozone layer may eventually repair itself.

Humans use CFCs in aerosol cans (in some countries), coolant in some refrigerators, and in the manufacturing of some plastics and foams. The percentage of human-produced CFCs are as follows:

Aerosols:	25%
Rigid Foam Insulation:	19%
Solvents:	19%
Air Conditioning:	12%
Refrigerants:	8%
Flexible Foam:	7%
Other:	10%

The term "**ozone depletion**" means more than just the natural destruction of ozone. It means that ozone loss is greater than ozone creation. Think again of the "leaky bucket." Putting additional chemicals like CFCs into the atmosphere is like causing the "bucket" of ozone to spring extra leaks. The extra leaks cause ozone to leak out at a faster rate--faster than ozone is being created. Consequently, the level of ozone protecting us from ultraviolet radiation decreases.

It is important to note that ozone, like oxygen, is a highly **reactive** element. It is so reactive that it is quite harmful when it comes into direct contact with life. In the stratosphere, ozone is a protector; on Earth's surface, it's a poison. Without it, though, life on Earth would be more difficult to maintain.

The text and graphics in this reading were adapted from the NASA Fact sheet NF-198 produced by the Earth Science Enterprise. The entire fact sheet can be found online at http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/eos/ozone.pdf